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SPECIES DIVERSITY, BIOMASS AND COMMUNITY STRUCTURE OF CEPHALOPODS OFF ADANG-RAWI ARCHIPELAGO, THAILAND

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ABSTRACT

The cephalopod fauna off the off Adang-Rawi Archipelago, Thailand, and adjacent areas, was investigated between December 1998 and April 1999 during the northeast monsoon season. Four families of cephalopods were found, namely Loliginidae (*Loligo duvauceli*, *L. chinensis*, *Loliolus sumatrensis* and *Sepioteuthis lessoniana*), Sepiidae (*Sepiella inermis*, *Sepia aculeata*, *S. pharaonis, S. lysidas, S. brevimana* and *S. recurvirostra*), Sepiolidae (*Euprymna stenodactyla*), and Octopodidae (*Octopus* spp.). The average catch rate and biomass were 4.34 kg h^{-1} and 320.66 t, respectively. The highest catches were in February (5.32 kg h^{-1}; 382.57 t), December (4.10 kg h^{-1}; 314.33 t) and April (3.61 kg h^{-1}; 265.07 t). Diversity measures were applied and three assemblages recognized, i.e., the western side of Tarutao Island, north and south of Adang-Rawi Archipelago. Salinity was the best-fitting environmental parameter and correlated with biotic pattern in the survey area.

Cephalopods are becoming more important for fisheries in the Andaman Sea. Cephalopod production in 1996 was 57,217 t and contributed 33% of total cephalopod production in Thai waters. The composition of the cephalopod catch in 1996 comprised cuttlefish 23,286 t, squid 23,229 t and octopus 10,702 t. Otter board trawl and pair trawl were the main gears employed, followed by purse seine and other small scale fisheries.

Surveys of the marine resources of the Adang-Rawi Archipelago and adjacent areas during 1977–1983 conducted by the Pramong III research vessel of Andaman Sea Fisheries Development Center (AFDEC) showed a steeply decreasing trend of catch rate, due to heavy harvesting by the commercial trawl fleet from Satul Province and adjacent areas. The target species were fish and cephalopods especially squid and cuttlefish. The spatio-temporal distribution, taxonomic composition, and abundance of cephalopods in the Andaman Sea have been studied previously (Chantawong et al., 1984; Chotiyaputta et al., 1992; Nateewathana, 1997; Chantawong and Suksawat, 1997), but not species diversity and production at the fishing grounds. Changes in species composition of marine resources may be caused by many factors, such as natural fluctuations in abundance, over-exploitation, and/or changes in environmental conditions of both nearshore and offshore areas.

The objective of the present study is to investigate catch rate and biomass; size composition; diversity of the cephalopod community in relation to environmental parameters of the Adang-Rawi Archipelago and adjacent areas.

Materials and Methods

The Adang-Rawi Archipelago is located in the Tarutao Marine National Park, south of the Thai Andaman Coast of Satul Province (Fig. 1). In 1998 and 1999, systematic monitoring of the marine resources were conducted by AFDEC, the Marine Fisheries Division, Department of Fisheries, Thailand. Three cruises were carried out during the Northeast (NE) monsoon in December 1998,

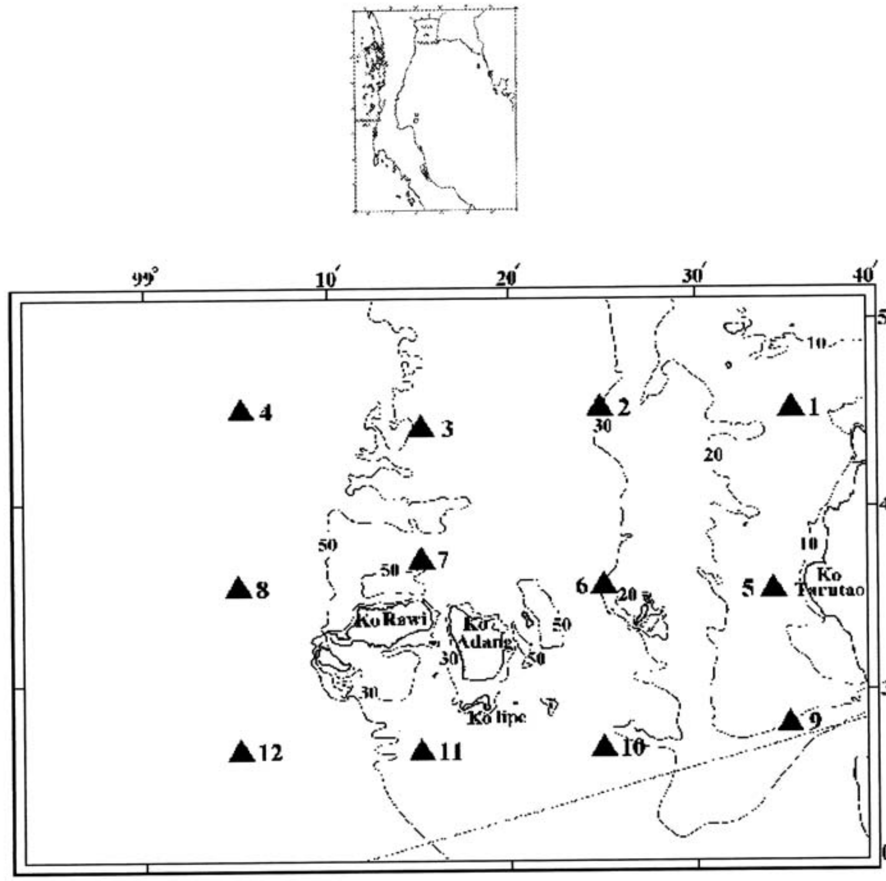

Figure 1. Survey stations for marine resources () off Adung-Rawi Archipelago and the adjacent areas of Satul Province, Thailand.

February and April 1999. The RV Pramong III with an otter-board bottom trawl of upper head rope of 39.0 m with a codend of 4.0 cm mesh size surveyed 12 stations during daylight hours. The towing time was 1 hr at 2–3 kt per station, positioned in a fixed grid covering approximately 3550 km^2. Environmental parameters; such as water depth, bottom temperature and bottom salinity were collected by CTD recorder.

Cephalopods caught were identified to family and, whenever possible, to species level. The identification of cephalopods was based on Roper et al. (1984) and Chotiyaputta et al. (1992). Catch composition and relative abundance of cephalopods were calculated to estimate the biomass. The mean catch per unit effort or per unit of area was used as a stock abundance index. Biomass was estimated by the swept-area method using the stock abundance index (Sparre, 1985). It was assumed that trawl width was 0.5 × head rope length and the proportion of fish retained in the swept area (or catchability) was 0.5 (Sparre and Venema, 1992).

Cluster analysis and non-metric Multi-dimensional Scaling Ordination (MDS) (Kruskal and Wish, 1978) were carried out based on a Bray-Curtis similarity matrix of appropriately transformed species abundance data (catch rate, kg h^{-1}). For univariate community analysis, the indices used were the Shannon-Wiener diversity index, Pielou's evenness index, and Simpson's dominance index (Carr, 1997).

Analysis of Similarity (ANOSIM) and Similarity percentages (SIMPER) were used for analysis of cephalopod species similarity and species ranking of average dissimilarity between assemblage, respectively. Changes in community structure were related to environmental variables and site by BIOENV (Biotic to environmental procedure). All the above were carried out by PRIMER (Carr, 1997).

Results

Species Encountered.—The cephalopods recorded in this survey belonged to three orders, four families, seven genera, and 12 species as follows:

Order Sepioidae
- Family Sepiidae
  - *Sepia pharaonis* Ehrenberg, 1831
  - *Sepia recurvirostra* Steenstrup, 1875
  - *Sepia aculeata* d'Orbigny, 1848
  - *Sepia brevimana* Steenstrup, 1875
  - *Sepia lysidas* Gray, 1849
  - *Sepiella inermis* Férrussac & d'Orbigny, 1848
- Family Sepiolidae
  - *Euprymna stenodactyla* (Grant, 1835)

Order Teuthoidae
- Family Loliginidae
  - *Sepioteuthis lessoniana* Lesson, 1830
  - *Loligo chinensis* Gray, 1849
  - *Loligo duvauceli* d'Orbigny, 1848
  - *Loliolus sumatrensis* d'Orbigny, 1835

Order Octopoda
- Family Octopodidae
  - *Octopus* spp.

Catch, Biomass and Size Distribution.—Adang-Rawi Archipelago is one of the most productive areas in the Andaman Sea and coral reefs are a major coastal feature. Average CPUE and biomass of cephalopod resources were 4.34 kg h^{-1} and 320.66 t and accounted for 17% of the total catch of marine resources. The cephalopod component from the area were squid (Loliginidae) 90.45%, cuttle fish (Sepiidae) 6.41%, octopus (Octopodidae) 3.12% and sepiolids (Sepiolidae) 0.02% in weight. The most dominant loliginid was *L. duvauceli* (67.94%), followed by *L. chinensis* (16.79%), *L. sumatrensis* (7.89%) and *S. lessoniana* (7.38%). *L. chinensis* was the largest species of squid, ranging from 72 to 240 mm (Fig. 2). The most dominant species of cuttlefish was *S. pharaonis* (27.97%), followed by *S. aculeata* (20.98%), *S. inermis* (20.98%), *S. lysidas* (20.98%), *S. brevimana* (6.99%), and *S. recurvirostra* (2.10%) of the total cuttlefish in weight. *S. aculeata* was the largest species of cuttlefish (Fig. 2).

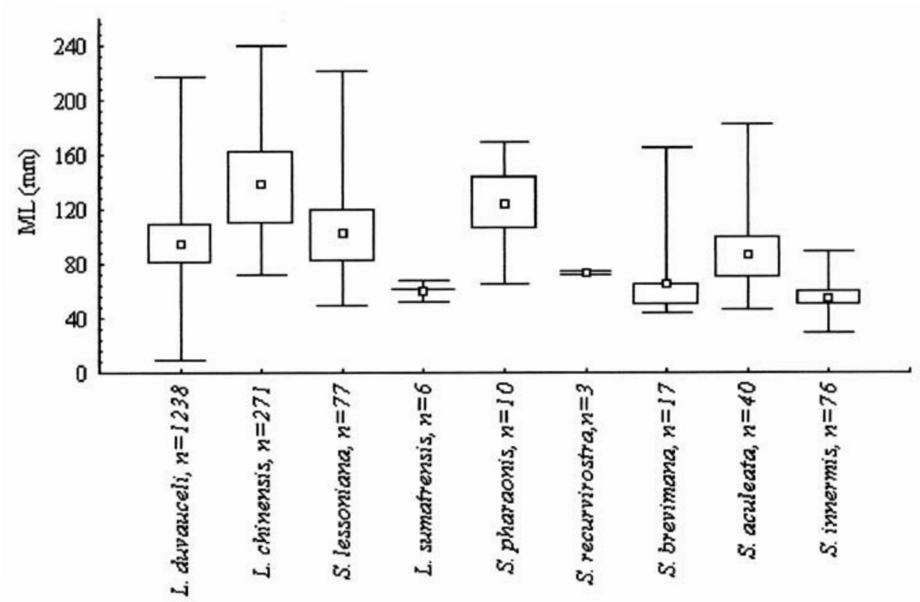

Figure 2. Size distribution of cephalopod species in 1998 and 1999 (Box & Whiskers Plots).Size range (bar), mean (small box) and 25–75 percentile (large box) of mantle length (ML). n = number of samples

Table 1 shows the average CPUE and biomass of cephalopods from all cruises. The highest catches of cephalopods were obtained in February.

In a one-way ANOVA and Least Significant Difference test (LSD), the difference of CPUE between cruises was significant ($P < 0.05$) for Loliginidae (in February and April) and Sepiidae (in February, December and April).

Environmental Factors.—Figure 3 illustrates the variation of water depth, bottom temperature and bottom salinity at each station on all cruises (locations shown in Fig. 1). Water depth and bottom salinity increased from nearshore to offshore, whereas the bottom temperature showed the reverse. The highest variation of bottom temperature and bottom salinity was in February and April. In February, the bottom temperature each station was the lowest recorded.

Community Structure.—The species richness, diversity, evenness and dominance indices of cephalopod resources in this study were 12, 1.33, 0.54, and 0.41, respectively (Table 2). The total number of species and dominance were highest in December than

Table 1. Catch per unit of effort (CPUE, kg h^{-1}) and biomass (tonne) of cephalopods in the Adang-Rawi Archipelago and adjacent areas of Satul Province, Thailand, in 1998 and 1999.

Item	Loliginidae		Sepiidae		Sepiolidae		Octopodidae		Cephalopod	
	CPUE	Biomass	CPUE	Biomass	CPUE	Biomass	CPUE	Biomass	CPUE	Biomass
Dec.	3.93	302.40	0.16	11.18	0	0.15	0.01	0.60	4.55	314.33
Feb.	5.08	363.36	0.17	14.30	-	-	0.07	4.91	5.32	382.57
Apr.	2.77	205.45	0.52	38.21	-	-	0.32	21.40	3.61	265.06
All	3.93*	290.40	0.28**	21.24	0	0.05	0.13	8.97	4.34ns	320.66

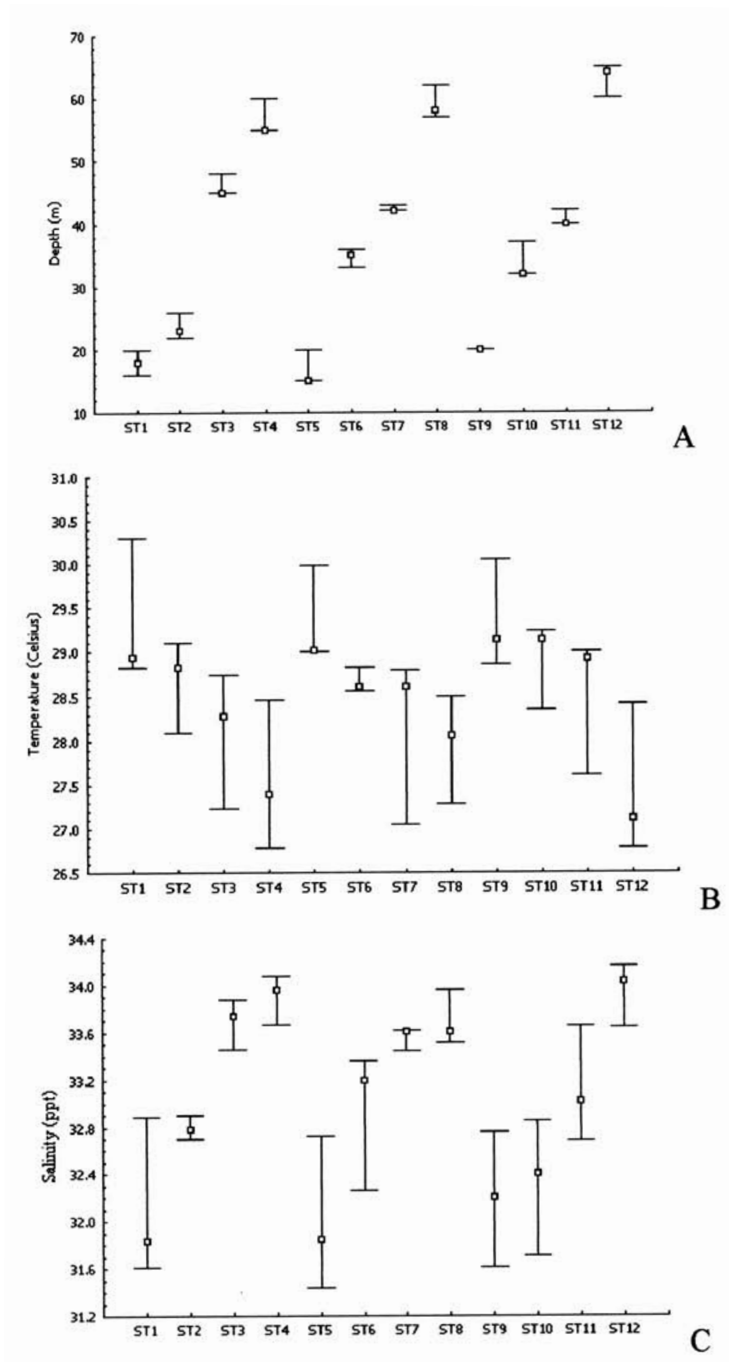

Figure 3. Range (bar) and median (small box) of depth of water depth (A), bottom temperature (B) and bottom salinity (C) at stations sampled off Adang-Rawi Archipelago in 1998 and 1999 (Whiskers Plots). ST station

Table 2.The total number of species (S), diversity (H), evenness (J) and dominance (D) in 1998 to 1999.

Cruise	S	H	J	D
December 1998	12	0.85	0.34	0.64
February 1999	11	1.11	0.46	0.47
April 1999	10	1.83	0.79	0.21
1998–1999	12*	1.33**	0.54**	0.41**

* Significant difference between December and April.

** Significant difference between February, April and December.

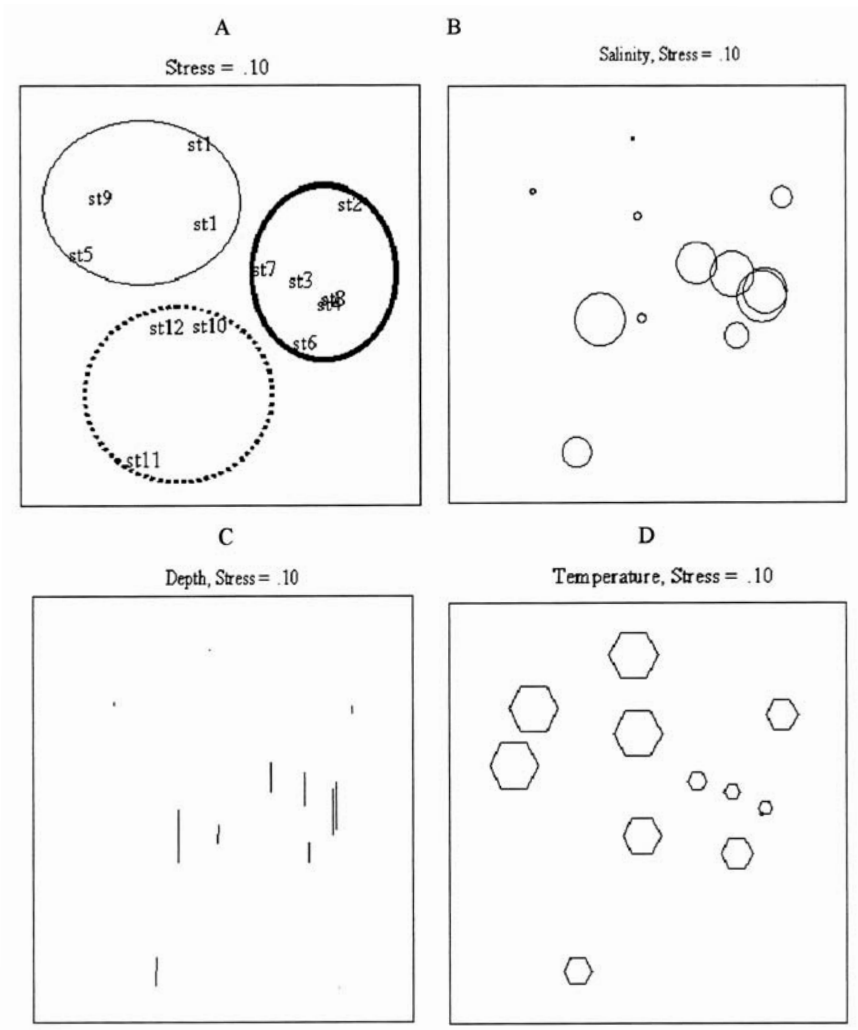

Figure 4. Adang-Rawi Archipelago, (A) MDS ordination plot showing west of Tarutao Island (thin line), north of Adang-Rawi Archipelago (thick line), south of Adang-Rawi Archipelago (dash line); (B) The same MDS, but with salinity superimposed, circle diameters related to increasing salinity; (C) The same MDS, but with depth superimposed, line length related to increasing depth ; (D) The same MDS, but with temperature superimposed, pentagon diameters related to increasing temperature. Stress is the measure of goodness-of-fit of the regression for MDS.

Table 3.Breakdown of average similarity between group 1, 2, 3 into contributions from species list and average catch rate off Adang-Rawi Archipelago.

Item	Group 1 kg h^{-1}	Item	Group 2 kg h^{-1}	Item	Group 3 kg h^{-1}
L. duvauceli	1.95	*L. duvauceli*	3.64	*L. duvauceli*	2.67
L. chinensis	0.59	*L. sumatrensis*	0.66	*L. chinensis*	0.73
S. aculeata	0.18	*S. aculeata*	0.05	*S. lessoniana*	0.34
S. inermis	0.21	*L. chinensis*	0.61	*L. sumatrensis*	0.36
L. sumatrensis	0.18	*Octopus* spp.	0.02	*S. pharaonis*	0.16
Octopus spp.	0.35	*S. brevimana*	0.01	*S. brevimana*	0.01
S. lessoniana	0.20			*Octopus* spp.	0.05
S. lysidas	0.16			*S. recurvirosta*	0.01
S. brevimana	0.02				
Cephalopods	3.84		4.99		4.33

February and April. Diversity and evenness were greatest in April, followed by February and December (Table 2).

In a one-way ANOVA and LSD, the difference between cruises was significant ($P < 0.05$) for all variables.

Ordination analysis categorized cephalopod catches into three assemblages composed of group 1; west of Tarutao Island, group 2; south of Adang-Rawi Archipelago, and group 3; north of Adang-Rawi Archipelago (Fig. 4A). ANOSIM showed significant differences between groups ($R = 0.59$ group 1 and 2, $R = 0.90$ group 1 and 3, and $R = 0.80$ group 2 and 3). Table 3 showed the species list and catch rate based on a breakdown of average similarity for each assemblage. Group 1 has the highest total number of species and the lowest of catch rate. Group 2 has the lowest total number of species and the greatest catch rate, in which *L. duvauceli* was dominant. Superimposing the environment parameters, we can see that the biotic pattern shows a low correlation with the values for salinity (Fig. 4B ($r = 0.24$)).

Discussion and Conclusion

The water off Adang-Rawi Archipelago is an important fishing ground for the cephalopods located north of the boundary line between Thailand and Malaysia. Cephalopods, especially squid and cuttlefish, are migratory shared stock moving between Thai and Malaysian waters (Chantawong 1999). Cephalopods found in the present study comprised three orders, four families, seven genera, and 12 species. Cephalopods of the Andaman Sea comprise of 53 species, 23 genera, 14 families and four orders (Chotiyaputta, 1993; Nateewathana, 1997). Coastal areas off Phang-Nga Bay and the northern part of Phang-Nga Province recorded five species of squid, five species of cuttlefish, one species of sepiolid, and one genus of octopus (Chantawong et al*.,* 1996; Chantawong and Suksawat, 1997). *Loligo singhalensis*, generally distributed at the northern part of Phang-Nga Province, was not recorded in the present study.

The maximum catch rate and biomass (4.34 kg h^{-1} and 320.66 t) of cephalopods found during the NE monsoon which a decrease from 1995 (7.91 kg h^{-1} and 485.00 t) (Chantawong 1999). The abundance in February showed highest followed by December and April. Ingredient of bottom temperature and bottom salinity in February displayed lower each station than in April and December. Cause of increasing of cephalopods abundant in February might be correlated with the changing environment parameters and/or migration of others stock from neighbor waters. Main component of cephalopods was squid (*L. duvauceli* and *L. chinensis*), cuttlefish (*S. pharaonis*, *S. aculeata*, *S. inermis*, *and S. lysidas*), and octopus (*Octopus* spp.). The study on cephalopods abundance and composition agreed with Chantawong *et al*. (1996). Cephalopods composition off the northern part of Phang-Nga Province was composed of squid, octopus, cuttlefish and sepiolid squid was operated during night-time (Chantawong and Suksawat, 1997). They also reported that the size of *L. singhalensis* and *S. pharaonis* caught were bigger than those of squid and cuttlefish. The big size of squid and cuttlefish observed from this study were *L. duvauceli* and *S. aculeata*.

There was considerable variability in the measured environmental parameters between sampling occasion in this study. Depth of water and bottom salinity showed increasing from near-shore to off shore when bottom temperature found opposite that decreasing from near-shore to off shore stations. Consequence, to what extent this variability is related to water run off from main land at near shore areas and intruded from deep water in open sea at off shore areas.

Diversity measured of cephalopods at present study showed 12 total number of species, 1.33 diversity, 0.54 evenness and 0.41 dominance. The west of Tarutao Island and Adang-Rawi Archipelago were great value of diversity and evenness but lows dominance.

Cephalopod community shows a clear separation assemblages are west of Tarutao Island, north and south of Adang-Rawi Archipelago. The west of Tarutao Island found highest total number of species and lowest of abundance. At the north of Adang-Rawi Archipelago showed lowest total number of species and greatest abundance with the bulk of *L. duvauceli*. Total number of species and abundance in the rest assemblages showed higher than north of Adang-Rawi Archipelago and west of Tarutao Island, respectively. From the analysis of the rank correlation between biotic and abiotic similarity matrices, the results can be meaningful and useful. During surveys in NE monsoon, the relative showed importance of bottom salinity.

Waluda and Pierce (1998) reported relationship between squid distribution and sea temperature and salinity in United Kingdom Waters, bottom temperature was most frequently correlated with catch rate of squid. They also reported that squid catch rate was positively associated with surface and bottom salinity. Many studies on tropical water assemblages of continental shelf and upper slope indicated that changes in species composition are depth related (Mcmanus, 1985; Role, 1987; Qiu, 1988; Bianchi, 1991, 1992).

Relationships between oceanographic parameters and squid distribution and abundance have been widely reported in the literature. Some studies identify putative physiological limits whereas most report correlations, either on a temporal or spatial basis, between abundance and one or more physical variables. The underlying causal relationship is usually unknown, but several types of explanation may be suggested; physiological tolerance limits effect on growth and mortality; possibly mediated by changes in prey abundance; adaptive behavioral preferences; effort on catchability; increased metabolic activity at higher temperature; indirect relations related to changes in current systems.

Studies on cephalopods in the Andaman Sea area are still insufficient, especially biological information (for example, length-weight relationships, size at maturity, spawning ground, spawning season, growth parameters, change in cephalopod communites and related with oceanographic parameters). Therefore, further surveys should be conducted to obtain information on parameters controlling cephalopod population in the Andaman Sea in order to develop resource management methods for cephalopods.

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